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Channel 21 television transmissions:
Interference to services below 470 MHz

No. 1971/34

Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION

RESEARCH DEPARTMENT

CHANNEL 21 TELEVISION TRANSMISSIONS: INTERFERENCE TO SERVICES BELOW 470 MHz

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Summary

Some types of communication equipment that are used by public services at frequencies in the private mobile radio band operate just below 470 MHz. The results are given of laboratory tests to determine the susceptibility of this equipment to interference from lower-sideband radiation from Channel 21 television transmitters. The operational factors affecting the incidence of interference are discussed and specifications are given which give the minimum permissible lower-sideband attenuation and the maximum interfering field strength. The characteristics of an ideal check receiver are discussed and an experimental model is briefly described.

1. Introduction

The lower limit to Band IV, allocated to u.h.f. television broadcasting, is 470 MHz. The lowest-frequency channel in Band IV is Channel 21 which is assigned a vision-carrier frequency of 471·25 MHz. The carrier amplitude is modulated by video frequencies up to 5·5 MHz but the lower sideband is restricted by a filter before transmission. In the normal way the specification of this filter would be similar to that used on other u.h.f. television channels to prevent undue adjacent-channel interference, but this filtering may not be sufficient to protect other services near the band edge even where CCIR recommendations are followed.* Since a vestigial lower sideband, 1·25 MHz wide, must be transmitted without attenuation (U.K. Standard I), it is impossible to prevent interference to reception at frequencies immediately below 470 MHz and difficult at other frequencies in the 465 to 470 MHz region. This region contains bands allocated to mobile radio services. In particular, two bands, which lie between 4·5 MHz and 6 MHz below the vision-carrier frequency of Channel 21, are allocated to the Home Office for transmissions received at base stations from police personal radio (Pocketfone) equipment using narrow-band frequency-modulation. Where base stations and Channel 21 television relay transmitters are sited in the same areas the television field strength at one or more base stations may be high enough to cause interference. Both the television relay and police transmissions (and hence the corresponding receiving aerials) are normally vertically polarised, whereas interference from main television stations operating on Channel 21 is less likely because these use horizontal polarisation.

This report describes the results of the laboratory tests to find the susceptibility of the police equipment to interference from a television transmission. First, the equipment and frequency bands used by the police services are briefly indicated. Second, the lowest values of field strength of the police service signals at which the receiving equipment continues to function satisfactorily are discussed. Third, the response of the equipment to a television signal is given, with corrections to allow for mistuning. Last, the results are presented in two forms to show the maximum tolerable level of an interfering television signal and also the minimum tolerable ratio of the upper sideband to the lower sideband of the channel 21 transmission, assuming a probable maximum value for the received vision-carrier level.

*CCIR Recommendation 329, Oslo, 1966, suggests that out-of-band signal power in a television transmitter feeder should not exceed either 60 dB below the carrier power, or 20 mW, whichever is the greater.

2. Services in the 465 to 470 MHz band

2.1 Mobile transmitters

The frequency bands allocated to the Home Office in the 5 MHz below 470 MHz are shown in Fig. 1. The bands used by the most vulnerable service, i.e. that of the low-power police personal (Pocketfone) transmitters working to fixed receiving sites, are shown by the shaded areas in Fig. 1 and extend roughly from 4·5 MHz to 6 MHz below the vision-carrier frequency of channel 21. The two bands are divided into 51 channels of 25 kHz width. At the present time, two types of equipment are in operational use,

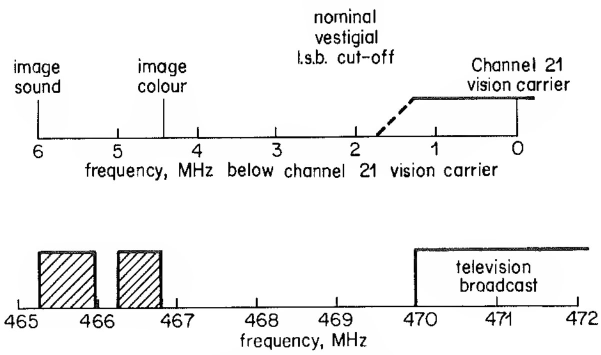

Fig. 1 - Frequency spectrum between 465 MHz and 472 MHz

bands allocated to police personal transmissions

designed for 25 kHz and 50 kHz channel separation, with the 25 kHz equipment gradually superseding the 50 kHz equipment. The transmitter frequency is crystal-controlled; the carrier power is about 100 mW and it is frequency-modulated by amplitude-limited speech which is attenuated at frequencies above 3 kHz. Performance specifications limit the frequency deviation and frequency drift as shown in Table 1.

TABLE 1

Performance of Pocketfone transmitter

Channel width kHz	Max. deviation, ± kHz at mod. any	Max. deviation, ± kHz at mod. 6 kHz	Max. frequency drift ± kHz	Performance specification
25	5	1·5	3·0	MPT 101
50	15	3	5·0	W 6304

2.2 Fixed receivers

Each receiving site for Pocketfone transmissions is operated with a vertically polarised, omni-directional aerial with an effective gain (less feeder loss) of about 4 dB. Each receiver is fitted with a "squelch" circuit to mute the audio output when the wanted signal is below a predetermined level. (Some differences were found in the behaviour of the squelch circuits in receivers of different manufacture.) Of the receivers used for the tests, all would operate positively and give easily intelligible reception with a carrier input level of 1 μV e.m.f., corresponding to the signal provided by the aerial and feeder, described above, in a wanted-signal field strength of 10 dB (μV/m) at 470 MHz. At an input level 5 dB lower than this, operation and intelligibility were only just tolerable in the absence of interference.

The permissible frequency drift of the base receiver is not known but it may be assumed to be no worse than that of a base transmitter, namely ± 2·5 kHz for the 25 kHz channel equipment and ± 3·5 kHz for the 50 kHz channel equipment.

3. Operational factors

3.1 General survey

The impairment caused to the reception of a Pocketfone signal will depend on many factors; these are discussed below.

3.1.1 Pocketfone field strength

Pocketfone transmissions over distances approaching the operational limit will be most affected by noise and interference. A field strength of 10 dB (μV/m), as indicated above, will be about 5 dB above the noise-limited minimum and is a suitable value to take for the minimum field strength to be protected from interference.

3.1.2 Channel 21 e.r.p.

The effective radiated power of the television transmitter may depend on the bearing from the transmitter and is normally fixed by the requirements of the television service area. If the transmitter is a relay, the aerial will have the same polarisation (vertical) as the police service receiving aerial. If the transmitter is a main station, an effective attenuation of about 15 dB may be allowed owing to cross-polarisation.

3.1.3 Operating frequency and nature of the television picture

Fine detail and saturated colours will increase the power in the television sidebands and increase the probability of interference to services using the lower sideband. In particular, services using frequencies close to the colour image frequency (466·82 MHz) will be most liable to interference during a transmission of colour bars. It may be feasible to prohibit the transmission of colour bars from certain stations, should it prove desirable. It would probably not, however, be feasible to avoid the transmission of the standard Test Card 'F' which contains twelve lines of colour bars on each field.

3.1.4 Upper-to-lower sideband ratio

The upper-sideband radiation from the transmitter will have a level determined by the vision-carrier level and the picture modulation. The lower sideband, which may directly or indirectly cause interference with services below 470 MHz, is attenuated, by the vestigial side-band filter at each main television transmitter and by additional filters at each relay transmitter. If the transmission system were perfectly linear, the upper-to-lower sideband ratio at the service receiver, measured as a function of the video modulating frequency, would be given by the product of the transmitter-filter responses and would be independent of the transmitted carrier level and of the picture modulation. In practice, non-linearity causes intermodulation in the relay transmitter which generates lower sideband components, so that an image sound signal may appear and the magnitude of the image colour signal may be larger than expected from a knowledge of filter characteristics.

3.1.5 Spatial separation between television transmitter and police service receiver

In a populated area served by a channel 21 television relay transmitter there may be many fixed base-stations for receiving police transmissions. In general, the base station which is nearest to the Channel 21 transmitter will suffer the greatest interference on any particular service frequency, but aerial directivity may have to be considered in some cases.

3.1.6 Frequency drift between police service transmitter and receiver

Figures for the maximum permissible frequency drift have been given in Table 1. An error in frequency will clearly make the reception of a given strength of signal more liable to interference.

3.1.7 Intermodulation in police service receiver

The police service receiver may have sufficient r.f. bandwidth and non-linearity for the received Channel 21 vision-carrier and its upper sideband to generate lower sideband components by a third-order intermodulation process. Unless the receiver is designed specifically to prevent this, by suppressing input signals at frequencies above 470 MHz, it may generate interference to signals below 470 MHz. It will be assumed in this report that adequate filtering has been provided in the receiving installation to ensure that intermodulation in the receiver is not the limiting factor. The conditions in which such filtering may be desirable are indicated in Section 4.2.

3.2 Practical limits

The variable quantities which contribute to interference have been surveyed in Section 3.1. Some guidance was required in order to set an upper limit to the level of the field strength of a television signal likely to occur in practice. To this end, a study was made of the distribution of service receiving sites in the vicinity of the proposed Channel 21 relay transmitter at Bromsgrove. This showed that, for the proposed vision carrier e.r.p. of 10 kW, the maximum vision-carrier field strength at the nearest service receiver, 3 km away, would be 107 dB (μV/m).

The police service carrier field strength requiring protection was 10 dB (μV/m) (see Section 3.1.1) and laboratory measurements were carried out to find the effective field strength of a vision carrier, double-sideband-modulated by a television picture, which produced just-acceptable interference at different carrier-frequency separations. As indicated below, the ratio between the measured carrier field strength and the limiting value of 107 dB (μV/m) gives the upper-to-lower sideband ratio required to protect police-service reception. This generally requires additional filters at the transmitter which are considered practicable, though protection for sites where the vision-carrier field strength is higher than the case considered may be difficult and unduly expensive.

4. Laboratory measurements

4.1 Interference from vision lower sideband

The arrangement is shown schematically in Fig. 2. A speech modulation voltage was applied across the microphone of the Pocketfone transmitter which was operated in a screened box. The frequency-modulated r.f. output was taken from a small coupling loop in the screened box and mixed with a double-sideband television signal before passing into the base receiver. In order to simulate reception of a 10 dB (μV/m) signal on the type of aerial used at the base station, the Pocketfone signal level at the receiver input was adjusted to 1 μV and the vision-carrier level was noted at which speech intelligibility was impaired but still tolerable. The results are shown in Fig. 3, which gives the field strength of the vision-carrier which would give just tolerable interference at different frequencies and for different picture modulations, using the service equipment designed for 50 kHz channelling. By using a full, double-standard signal for the measurements, Fig. 3 ignores the effect of any filtering which would normally be applied to attenuate the lower sideband. The difference between the figures given in Fig. 3 and the vision-carrier field strength occurring in a practical situation represents the total attenuation necessary to give protection. Similar measurements were made for the 25 kHz channel equipment which was less susceptible to interference; the results will be included later.

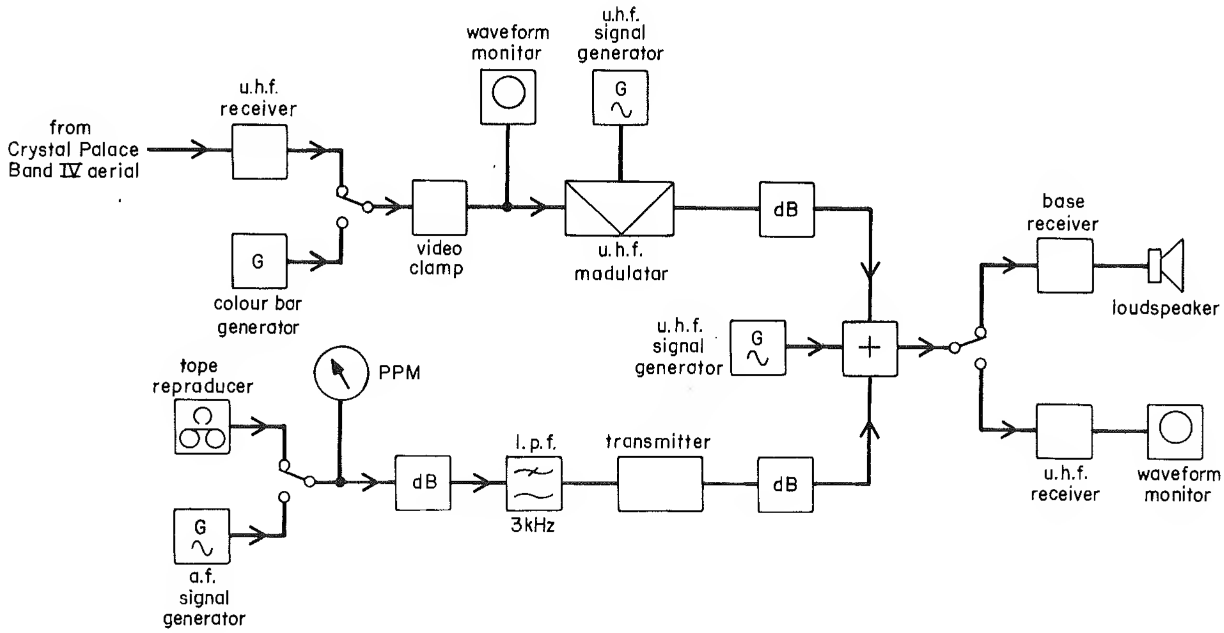

Fig. 2 - Schematic of test equipment

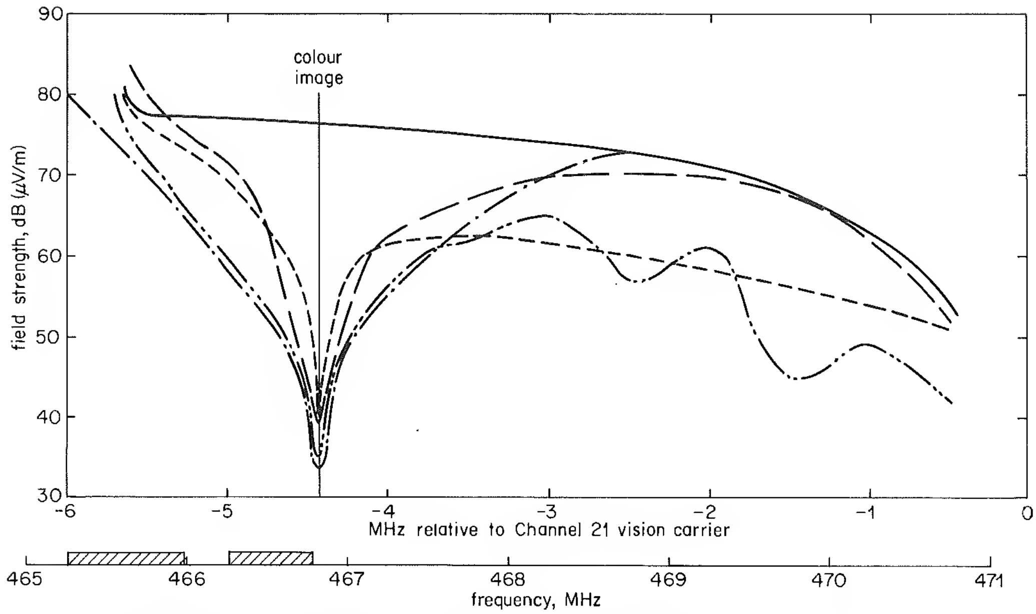

Fig. 3 - Maximum field strength of double sideband Channel 21 television transmission giving protection to reception of a 10 dB (μV/m) transmission by police equipment using 50 kHz channelling

———— black and white film	—·—·— 95% colour bars
— — — (trade test film (studio programme	—··—·· Test card 'F'
- - - - - cricket programme	▨ allocated to police personal transmissions

4.2 Interference from image sound signal

As mentioned already, intermodulation in a relay transmitter can cause unwanted lower sideband signals to be generated. For example, it may produce a signals (denoted by "image sound" in Fig. 1) at a frequency which is 6 MHz below the vision carrier. Such a signal would be frequency modulated by the sound signal and amplitude modulated by the square of the composite video waveform. This signal was simulated in the laboratory and the just tolerable signal level was measured; these just-tolerable image-sound signal levels correspond to peak field strengths, at an actual service receiving aerial, of 14 dB (μV/m) for the 50 kHz equipment and 12 dB (μV/m) for the 25 kHz equipment

Measurements of intermodulation occurring within a typical police service receiver indicate that this may cause intolerable interference if the vision-carrier field strength exceeds 100 dB (μV/m) and that, in these conditions, the receiver should be fitted with a filter which attenuates the vision-carrier.

4.3 Interference in presence of frequency drift

The measurements described in Sections 4.1 and 4.2 were carried out with no frequency error between the service transmitter and receiver. A restricted series of measurements was also made with a Pocketfone frequency-drift corresponding to the maximum shown in Table 1: the reduction of interference which gave the same protection is shown in Table 2. Also shown in Table 2 are the results for an even larger frequency drift, assuming that the Pocketfone transmitter and the base receiver have the maximum drift in opposite directions, a situation which is conceivable though unlikely. For this measurement, the base receiver drift was assumed to be equal to that permitted for a fixed transmitter. In the absence of interference, detuning causes some loss of sensitivity, but this was found to be a relatively unimportant factor.

Table 2

Channel width kHz	Frequency drift, ± kHz T = Mobile Transmitter R = Fixed Receiver	Reduction, dB, in interfering signal level required
25	3·0 T alone 5·5 T + R	2·0 6·0
50	5·0 T alone 8·5 T + R	2·5 5·0

5. Formulation of a specification for protection against interference

5.1 Two alternative methods

The interference may be specified in two ways, either indirectly, as in Section 5.2, or directly, as in Section 5.3.

The indirect method involves the specification of two quantities, first, the field strength of the Channel 21 vision-carrier at the service receiving site and second, the upper-to-lower sideband ratio radiated by the transmitter at the sideband frequency concerned. Fig. 3 gives the tolerable Channel 21 field strength for unity sideband ratio. If the vision-carrier field strength at a receiving site is known, the laboratory results of Fig. 3 may be corrected to give a minimum permissible upper-to-lower sideband ratio; Section 5.2 gives an example. A field measurement of this ratio will be independent of the picture modulation only if the transmitter is free from intermodulation; it is therefore best to specify also some standard picture such as a test card.

The direct specification gives the maximum permissible interfering field strength at each receiving site measured within a bandwidth comparable with that of the police service receiver. This is an absolute quantity so that a method of measurement and a test transmission must be specified before a television station can be measured to see if there is adequate interference suppression. The direct specification is given in Section 5.3 and is discussed in Section 5.4.

5.2 Indirect specification

The ratio between the upper- and lower-sideband components of a Channel 21 television transmission, for video frequencies in the ranges 4·5 MHz to 5 MHz and 5·3 MHz to 6 MHz must be no less than that shown in Fig. 4 in order to protect reception of police service transmissions using 50 kHz or 25 kHz channelling at receiving sites where the Channel 21 vision-carrier field strength is 107 dB (μV/m). For areas where the Channel 21 field strength at the nearest service receiving site is lower than 107 dB (μV/m) the specification may be relaxed accordingly.

It is recommended that the measurement of the upper-to-lower sideband ratio be carried out during a television transmission of Test Card 'F' using a receiver with a bandwidth of about 30 kHz and a quasi-peak detector response.

5.3 Direct specification

The maximum field strength of the lower-sideband components of a Channel 21 television transmission which will give just-acceptable interference with reception of service transmissions using 50 kHz or 25 kHz channelling and operating in the frequency bands 465·25 MHz to 465·95 MHz and 466·25 MHz to 466·75 MHz, is 14 dB (μV/m) when measured during a transmission of Test Card 'F' using a receiver with a bandwidth of about 30 kHz and a quasi-peak detector response which has been calibrated against a c.w. signal or vision-carrier of known level.

The behaviour of the receiver referred to in the above specifications is discussed in the next section.

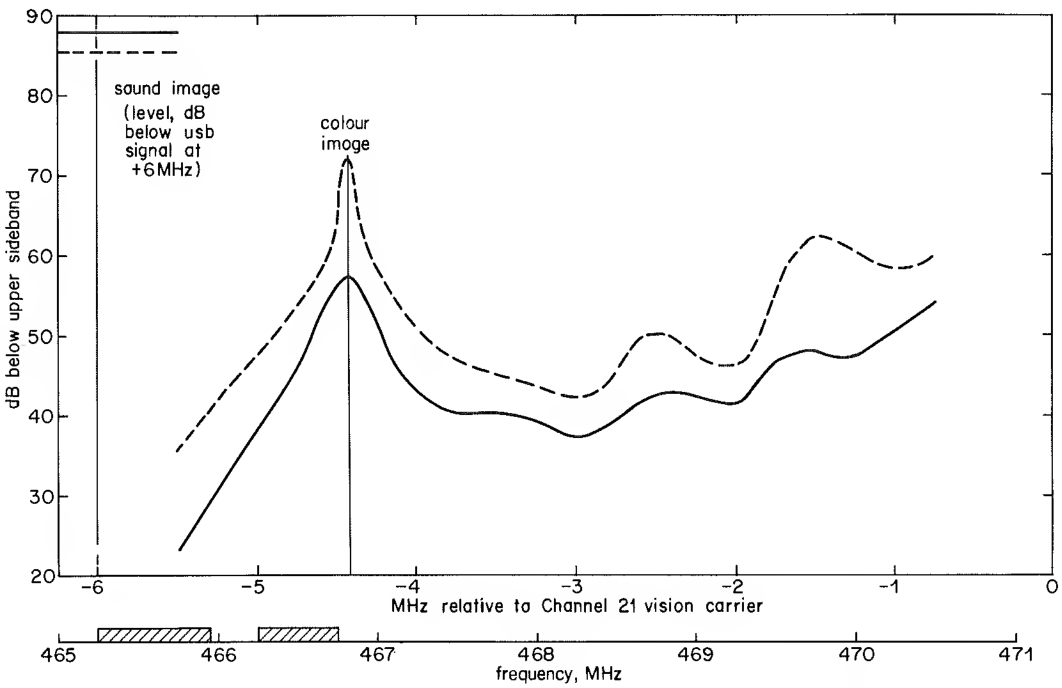

Fig. 4 - Minimum ratio of upper-to-lower sideband radiation for a Channel 21 television transmission giving protection to reception of a 10 dB (μV/m) police transmission

——— 25 kHz police equipment ---- 50 kHz police equipment ▨ allocated to police personal transmissions

5.4 Behaviour of an ideal check receiver

The ideal receiver for checking the direct specification described above must be designed to give an objective measurement of the interfering signal which corresponds closely to the subjective interference which it causes with the reception of the service signal. The check receiver and the service receiver should have a similar bandwidth so that each will intercept roughly the same power when tuned to the same point in the spectrum of the interference. In this case the appropriate bandwidth is between 15 kHz and 30 kHz so that at least one television-line-frequency component will always be included. The peak amplitude of the effective interference cannot therefore be greater than the highest value of the line-period integral of the signal, and we may give a value to this peak amplitude in certain circumstances. For example, when tuned to the vision-carrier frequency, the interference amplitude will have a peak value close to the peak vision-carrier (– 0·3 dB) during the field-synchronising-pulse period and will be almost independent of the bandwidth over the range 15 to 30 kHz. On the other hand, when tuned to the region of the colour sub-carrier sideband during a transmission of colour bars or Test Card 'F', the interference amplitude is dependent on both the tuning and bandwidth of the receiver. When the bandwidth is large, the peak amplitude is 17 dB below the peak vision-carrier during the cyan and red bars (95% saturation) but the phase-opposition of pairs of colour bars causes the mean value of the subcarrier and its even-order sidebands to tend to zero. At a bandwidth of 30 kHz, the peak signal level is about 21 dB below the peak vision-carrier for 95% colour bars. Referring to the subjective measurements of Fig. 3 for a double-sideband transmission, the peak vision-carrier has a field strength of 35 dB (μV/m) at the limit of acceptable interference to reception at the colour sideband frequency. The peak value measured by the check receiver will therefore be about 14 dB (μV/m), as given in Section 5.3.

The service receiver being considered has a frequency discriminator which, in common with all f.m. detectors, is subject to a so-called "capture effect" when the level of interference exceeds the wanted carrier level and causes a sudden loss of wanted modulation. If the check receiver has a detector which stores the peak value of the interference for 20 ms, (one television picture field period), then it will give an indication of the level of the wanted signal at which the capture effect occurs at some point of the picture.

Because the interference will not be constant at the peak value but will vary at the television field frequency and its harmonics, the wanted modulation will be intelligible even when the peak interference exceeds the wanted carrier level. This is why the specification given in Section 5.3, based on subjective experiments, corresponds to a figure of 14 dB (μV/m) for the maximum permissible peak interfering field strength, which is 4 dB greater than the (steady) value of the service field strength.

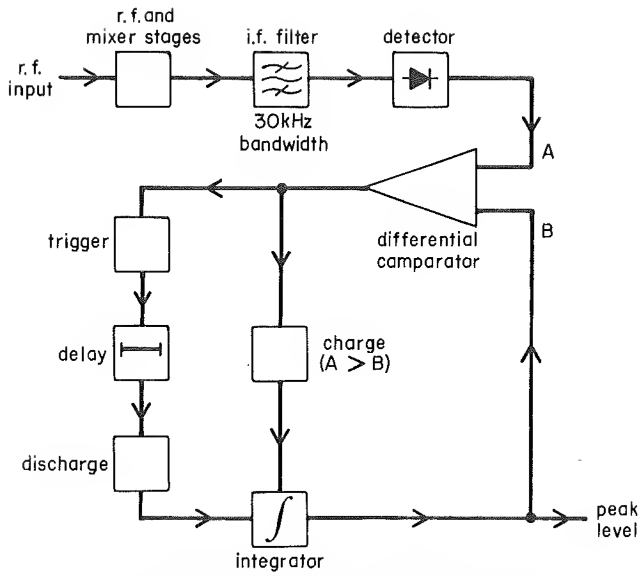

Fig. 5 - Schematic diagram of an experimental peak-reading check receiver

Fig. 5 shows a schematic of an experimental check receiver which has been used for measurements of the spectrum radiated by a television relay transmitter. The r.f., i.f. and detector units were those of a commercial spectrum analyser (Hewlett Packard 8554L and 8552A); the remainder were laboratory-built. In this application, the signal bandwidth is restricted to 30 kHz in the i.f. unit and the output of the envelope detector, A, is amplified in a differential comparator and held in an integrator. The voltage is held by the integrator at the level of the previous peak value, B, for a predetermined time delay. In practice, the integrator could reach the peak value of a single pulse with a duration of 2 μs and could hold the peak value for up to 200 ms before discharging at a selected rate. If desired, the charge, hold and delay times could, no doubt, be modified so that the measured quasi-peak interference approached the subjective value more closely and so that a minimum signal-to-interference ratio of unity could be specified.

6. Conclusion

Laboratory measurements have given the level of a television signal which will cause interference to narrow-band f.m. communications using frequencies within the television sidebands. From these results, figures have been derived for the minimum lower-sideband attenuation which would be necessary at a Channel 21 television transmitter in order to protect reception of service signals in the bands between 465 MHz and 470 MHz. Two forms of protective specification have been given and the properties of a suitable check receiver have been described. The results will enable the severity of possible interference to be assessed before television programmes are broadcast on Channel 21 and will assist in deciding whether or not Channel 21 should be used in any particular case.

DC/PF

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